(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 314 312 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification: **29.12.93** (51) Int. Cl.[5]: **G07D 7/00**, G01J 3/46

(21) Application number: **88309152.2**

(22) Date of filing: **03.10.88**

(54) Method and apparatus for detecting inks.

(30) Priority: **26.10.87 GB 8725034**

(43) Date of publication of application:
03.05.89 Bulletin 89/18

(45) Publication of the grant of the patent:
29.12.93 Bulletin 93/52

(84) Designated Contracting States:
CH DE ES FR GB IT LI SE

(56) References cited:
EP-A- 0 077 917
EP-A- 0 083 062
EP-A- 0 125 060
EP-A- 0 152 979
EP-A- 0 181 228
GB-A- 2 107 911

(73) Proprietor: **DE LA RUE SYSTEMS LIMITED**
6 Agar Street
London WC2N 4DE(GB)

(72) Inventor: **Martin, Anthony**
11 Cedar Drive
Porchester Hampshire(GB)
Inventor: **Lacey, Paul Dennis**
32 Mill Close
Denmead
Portsmouth, Hampshire, PO7 6PE(GB)

(74) Representative: **Skone James, Robert Edmund**
et al
GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH (GB)

EP 0 314 312 B1

Description

The invention relates to methods and apparatus for detecting the presence of an ink on a substrate.

It is known to print on substrates such as security documents and banknotes inks which, although appearing to have the same colour in the optical wavelength range, differ in their spectral absorption characteristics outside the optical range. We have devised a method and apparatus for detecting the presence of such inks.

GB-A-2107911 discloses a method and apparatus for detecting the presence of an ink on a substrate, the apparatus comprising irradiating means for irradiating the substrate with radiation of at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means for modulating the radiation at each wavelength in a respective, different manner; and radiation sensing means for sensing radiation emitted by the substrate.

In accordance with one aspect of the present invention, a method of detecting the presence of an ink on a substrate comprises irradiating the substrate with radiation at at least two different wavelengths, the radiation at each wavelength being modulated in a respective, different manner, and at least one of the wavelengths being chosen to correspond to an absorption or reflection wavelength of the ink to be detected; sensing radiation emitted from the substrate and correlating samples of the sensed radiation with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals; and monitoring the correlation signals in order to detect the presence of the said ink.

In accordance with a second aspect of the present invention, apparatus for detecting the presence of an ink on a substrate comprises irradiating means for irradiating the substrate with radiation at at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means for modulating the radiation at each wavelength in a respective, different manner; radiation sensing means for sensing radiation emitted by the substrate; correlating means for correlating samples of the sensed radiation from the radiation sensing means with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals; and monitoring means for monitoring the correlation signals in order to detect the presence of the said ink.

In our invention, the substrate such as a security document or banknote is irradiated with radiation at at least two different wavelengths and the response of the inks to the irradiation is monitored by modulating each wavelength in a unique manner and synchronously demodulating the received radiation by correlating that radiation with each of the modulation sequences. The result of the demodulation will be a number of correlation signals which vary in magnitude in accordance with the degree of correlation and the intensity of the received radiation at each wavelength. Provided that the modulations which are applied are sufficiently different, a correlation signal of a significant magnitude will only be generated when the received radiation includes a wavelength corresponding to the modulated signal which is correlated with it.

The invention has a number of advantages. In particular, broad band noise due, for example, to ambient light, is eliminated by the correlation technique. Also, the invention enables a single radiation receiver to be used.

Preferably, the modulations comprise phase shifted versions of a common modulation sequence such as a pseudo-random binary sequence. This leads to a very simple construction for the apparatus and, in the case of the use of a pseudo-random binary sequence enables well known correlation techniques to be adopted. This is discussed in more detail in "An Introduction to Identification" by J.P. Norton published by Academic Press (1986), pages 49-55.

Conveniently, the radiation sensing means comprises a common sensor for receiving radiation at each of the different wavelengths generated by the irradiating means.

It should be understood in this context that by "wavelength" we mean a band of wavelengths within which the wavelength in question is located, the wavelength bands not overlapping.

Correlation of the radiation can be achieved in a variety of known ways but is conveniently carried out by multiplying each sample of the sensed radiation with a respective one of the modulated signals and integrating the resultant multipled signals over a cycle of the modulation.

In any single apparatus according to the invention, the number of different wavelengths which can be used depends on the number of available modulations. In the case where phase shifted versions of a common modulation sequence are used, the number of wavelengths will depend on the length of the sequence.

To increase the number of wavelengths, a number of such apparatus according to the invention may be placed side by side. Furthermore, by providing more than one apparatus, the presence of an ink on

different parts of the substrate can be detected. In this case, if the modulations applied to each apparatus are different then each apparatus will be immune to stray irradiation from neighbouring apparatus.

The correlation signals may be monitored in a variety of ways. For example, where one signal corresponds to radiation in the optical waveband and another signal to radiation outside the optical waveband (for example infra-red) then the signals may be compared with each other or a ratio between the signals may be determined, the result of either of these operations being compared with a previously determined value to indicate the presence or absence of the ink. Thus, where two inks have the same colour in the optical waveband and different spectral responses outside the optical waveband, then the ratio between the respective signals will differ depending upon which ink is being irradiated.

The invention is applicable in a wide variety of applications but is particularly suitable for use with banknote sorting machines in which banknotes are sorted into acceptable and unacceptable types depending upon the presence or absence respectively of certain inks.

Typically, the radiation which is sensed will have been reflected from the substrate although alternatively radiation passing through the substrate could be sensed.

In order that the invention may be better understood, an example of a method and apparatus for detecting the presence of an ink on a document in accordance with the present invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of the apparatus;

Figures 2A and 2B illustrate two modulation sequences; and,

Figures 2C and 2D illustrate the signals output at two positions in the apparatus.

The apparatus shown in Figure 1 comprises a number n of light emitting diodes (LEDS) 1 which generate radiation at a corresponding number of different wavelengths some of which are in the optical range and some of which are outside the optical range, typically in the infrared range. The LEDS 1 irradiate a document 2 which is carried beneath the LEDS by means not shown. The wavelength of the radiation generated by at least one of the LEDs 1 is chosen to correspond with an absorption band of an ink which is expected to be printed on the document.

A single detector 3 is positioned above the document 2 to receive radiation reflected by the document. Alternatively, the detector 3 could be below the document.

The LEDs 1 are controlled by respective control lines 4 from a sequence generator 5 to generate respective modulated radiation beams in a manner to be described below. The sequence generator 5 generates respective modulation signals which are fed to the LEDs 1 which then generate the modulated radiation beams.

The output signal from the detector 3 which represents the intensity of the incident radiation on the detector 3, the detector 3 being responsive to all wavelengths generated by the LEDs 1, is fed in parallel to a set of multiplying circuits 6, one for each LED. In addition, each multiplier 6 receives the modulation signal from the sequence generator 5 corresponding to the associated LED 1, via respective lines 7.

The output signals from the multipliers 6 are fed to respective integrating circuits 8, the output signals from the integrators being fed to a microprocessor 9. The microprocessor 9 monitors the incoming (correlation) signals and generates output signals related to the inks which are detected as a result of that monitoring, the output signals being fed to an output device 10 such as a monitor or printer.

Since a common detector 3 is provided, it is necessary for the apparatus to distinguish between the different wavelengths of radiation which are reflected by the document 2. This is achieved by uniquely encoding each irradiation source (LED) 1 by modulating it with a pseudo random binary sequence (PRBS) generated by the sequence generator 5. An example of such a sequence is shown in Figure 2A. In order that each LED 1 is modulated with a different sequence, differently phase shifted versions of the sequence shown in Figure 2A are fed to the other LEDs 1. An example of a phase shifted version of the sequence is shown in Figure 2B.

The PRBS is a broad band signal with a correspondingly narrow autocorrelation function. This property is used to discriminate different signals or channels from one another. The autocorrelation function of the signal describes how well a signal correlates with shifted versions of itself and in the case of the PRBS this function will be zero unless the incoming signal is correlated with the same modulation sequence that generated it. In this way, noise due to ambient light and the like as well as stray light from other adjacent apparatus and wavelengths not associated with a particular channel are automatically eliminated.

Correlation is achieved by multiplying the two signals together in the multiplying circuits 6 which generate an output of the form shown in Figure 2C and subsequently integrating the result in the integrators 8 which generate an output of the form shown in Figure 2D. This system correlates the returned signal with each of the irradiation modulation sequences.

The correlation result used by the system processor can be defined mathematically as:

$$\emptyset(nT) = \emptyset(nT - T) \quad \text{for } t \neq nT \qquad n = 0 \ldots \infty$$

$$= \emptyset(t) \quad \text{for } t = nT$$

$$\text{and } \emptyset(t) = 0 \quad \text{if } t = nT + \delta T$$

$$= \frac{1}{A} \int_{nT + \delta T}^{n T + T} x(t)\, x(t + \tau)\, dt \quad \text{(a contiunous function)}$$

where

n	is the sample number
T	is the integregation period
x(t)	is the original sequence (FIG. 2A)
x(t + τ)	is the phase shifted sequence (FIG 2B)
A	is a scaling factor dependent on the system response.

The output signals from the integrators 8 indicate whether or not the wavelength associated with a particular channel has been reflected by the document 2 and in that case may indicate the presence of a particular ink which has the characteristic of reflecting radiation within that particular wavelength band. In practice, although n channels have been shown in Figure 1, a typical system would make use of just two channels.

The correlation signals are then compared by the microprocessor 9. In the case where just two channels are provided (corresponding for example to respective wavelengths in and out of the optical band), this comparison may involve determining the difference between the correlation signals and/or the ratio between the correlation signals and then comparing these values with predetermined calibration windows or thresholds. If the computed results fall within the windows or above the thresholds then an output signal is provided to the output device 10 indicating the presence of the ink concerned. This indication can then be used to control the feeding of the document in a conventional manner.

Claims

1. A method of detecting the presence of an ink on a substrate, the method comprising irradiating the substrate with radiation at at least two different wavelengths, the radiation at each wavelength being modulated in a respective, different manner, and at least one of the wavelengths being chosen to correspond to an absorption or reflection wavelength of the ink to be detected; and sensing radiation emitted from the substrate, characterised by correlating samples of the sensed radiation with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals; and monitoring the correlation signals in order to detect the presence of the said ink.

2. A method according to claim 1, wherein the modulations comprise phase shifted versions of a common modulation sequence.

3. A method according to claim 1 or claim 2, wherein the modulation comprises a pseudo-random binary sequence.

4. A method according to any of the preceding claims, wherein one of the wavelengths lies in the optical range, and another of the wavelengths lies outside the optical range.

5. A method according to any of the preceding claims, wherein the correlating step comprises multiplying each sample of the sensed radiation with a respective one of the modulated signals and integrating the resultant multipled signals over a cycle of the modulation.

6. A method according to any of the preceding claims, wherein the sensing step comprises sensing radiation reflected by the substrate.

7. Apparatus for detecting the presence of an ink on a substrate, the apparatus comprising irradiating means (1) for irradiating the substrate (2) with radiation at at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means (5) for modulating the radiation at each wavelength in a respective, different manner; radiation sensing means (3) for sensing radiation emitted by the substrate; characterised in that the apparatus further comprises correlating means (7,8) for correlating samples of the sensed radiation from the radiation sensing means with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals; and monitoring means (9) for monitoring the correlation signals in order to detect the presence of the said ink.

8. Apparatus according to claim 7, wherein the radiation sensing means (3) comprises a common sensor for receiving radiation at each of the different wavelengths generated by the irradiating means (1).

9. Apparatus according to claim 7 or claim 8, wherein the correlating means comprises a number of multiplying circuits (7), one for each wavelength, each multiplying circuit receiving a sample of the radiation sensed by the radiation sensing means and a signal which has been modulated in the same way as the radiation wavelength corresponding to that multiplying circuit; and integrating means (8) to which the output signal from the multiplying circuit is fed, the integrating means integrating the incoming signal over a cycle of the modulation.

10. Apparatus according to any of claims 7 to 9, wherein the modulating means (5) causes each wavelength to be modulated in a respective pseudo-random binary sequence.

11. Apparatus according to any of claims 7 to 10, wherein the modulating means (5) modulates the radiation at each wavelength with respective phase shifted versions of a common modulation sequence.

12. A method according to any of claims 1 to 6, wherein the substrate comprises a banknote.

Patentansprüche

1. Verfahren zum Feststellen der Anwesenheit einer Tinte auf einem Substrat, wobei das Verfahren beinhaltet: das Bestrahlen des Substrats mit einer wenigstens zwei verschiedene Wellenlängen aufweisenden Strahlung, von denen die eine Wellenlänge so gewählt ist, daß sie einer Absorptions- oder Reflexionswellenlänge der festzustellenden Tinte entspricht, und das Abfühlen der vom Substrat reflektierten Strahlung, gekennzeichnet durch das Korrelieren von Abtastwerten der abgefühlten Strahlung mit Signalen, von denen jedes durch jeweils eine der auf die Strahlung angewandten Modulationen moduliert wird, um Korrelationssignale zu erzeugen, und das Überwachen der Korrelationssignale zum Feststellen der Anwesenheit der erwähnten Tinte.

2. Verfahren nach Anspruch 1, bei dem die Modulationen phasenverschobene Versionen einer gemeinsamen Modulationssequenz umfassen.

3. Verfahren nach Anspruch 1 oder 2, bei dem die Modulation eine binäre Pseudo-Zufalls-Sequenz aufweist.

4. Verfahren nach einem der vorstehenden Ansprüche, bei dem eine der Wellenlängen im optischen Bereich und eine andere außerhalb des optischen Bereichs liegt.

5. Verfahren nach einem der vorstehenden Ansprüche, bei dem die Korrelation das Multiplizieren jedes Abtastwertes der abgefühlten Strahlung mit jeweils einem der modulierten Signale und die Integration der resultierenden multiplizierten Signale über eine Periode der Modulation umfaßt.

6. Verfahren nach einem der vorstehenden Ansprüche, bei dem das Abfühlen das Abfühlen der durch das Substrat reflektierten Strahlung umfaßt.

7. Vorrichtung zum Feststellen der Anwesenheit einer Tinte auf einem Substrat, wobei die Vorrichtung Bestrahlungsmittel (1) zum Bestrahlen des Substrats (2) mit einer wenigstens zwei verschiedene

Wellenlängen aufweisenden Strahlung, von denen die eine Wellenlänge so gewählt ist, daß sie einer Absorptions- oder Reflexionswellenlänge der festzustellenden Tinte entspricht, Modulationsmittel (5) zum Modulieren der Strahlung jeder Wellenlänge in jeweils unterschiedlicher Weise und Strahlungsfühlmittel (3) zum Abfühlen der durch das Substrat emittierten Strahlung aufweist, dadurch gekennzeichnet, daß die Vorrichtung ferner Korrelationsmittel (7, 8) zum Korrelieren von Abtastwerten der abgefühlten Strahlung aus den Strahlungsfühlmitteln mit Signalen, die jeweils durch eine der auf die Strahlung angewandten Modulationen moduliert sind, um Korrelationssignale zu erzeugen, und Überwachungsmittel (9) zum Überwachen der Korrelationssignale aufweist, um die Anwesenheit der erwähnten Tinte festzustellen.

8. Vorrichtung nach Anspruch 7, bei der das Strahlungsfühlmittel (3) einen gemeinsamen Fühler zum Empfangen der Strahlung mit jeder der verschiedenen Wellenlängen, die durch das Bestrahlungsmittel (1) erzeugt werden, aufweist.

9. Vorrichtung nach Anspruch 7 oder 8, bei der das Korrelationsmittel aufweist: eine Anzahl von Multiplizierschaltungen (7), und zwar jeweils eine für jede Wellenlänge, wobei jede Multiplizierschaltung einen Abtastwert der durch das Strahlungsfühlmittel abgefühlten Strahlung und ein Signal empfängt, das auf die gleiche Weise wie die Strahlungswellenlänge moduliert ist, die jener Multiplizierschaltung entspricht, und Integrationsmittel (8), denen das Ausgangssignal der Multiplizierschaltung zugeführt wird, wobei die Integrationsmittel das Eingangssignal über eine Periode der Modulation integrieren.

10. Vorrichtung nach einem der Ansprüche 7 bis 9, bei der das Modulationsmittel (5) bewirkt, daß jede Wellenlänge in einer zugeordneten binären Pseudo-Zufalls-Sequenz moduliert wird.

11. Vorrichtung nach einem der Ansprüche 7 bis 10, bei der das Modulationsmittel (5) die Strahlung jeder Wellenlänge mit zugeordneten phasenverschobenen Versionen einer gemeinsamen Modulationssequenz moduliert.

12. Verfahren nach einem der Ansprüche 1 bis 6, bei dem das Substrat eine Banknote aufweist.

Revendications

1. Méthode pour capter la présence d'encre sur un substrat, la méthode comportant l'irradiation du substrat par rayonnement un minimum de deux longueurs d'onde différentes, le rayonnement de chaque longueur d'onde étant modulé de façon respective différente, et le minimum d'une des longueurs d'onde étant sélectionné de manière à correspondre à une longueur d'onde d'absorption ou à de réflection de l'encre à capter; et le captage du rayonnement émis par le substrat, caractérisé par la corrélation des signaux d'échantillons de rayonnement capté avec des signaux dont chacun est modulé selon l'une des modulations respectives appliquées au rayonnement, de façon à générer des signaux de corrélation; et la surveillance des signaux de corrélation de façon à capter la présence de ladite encre.

2. Méthode suivant la revendication 1, selon laquelle les modulations comportent des versions déphasées d'une séquence commune de modulation.

3. Méthode suivant la revendication 1 ou la revendication 2, selon laquelle la modulation comporte une séquence binaire pseudo-aléatoire.

4. Méthode suivant l'une ou l'autre des revendications précédentes, selon laquelle l'une des longueurs d'onde est située dans un éventail optique et l'autre longueur d'onde est située hors de l'éventail optique.

5. Méthode suivant l'une ou l'autre des revendications précédentes, selon laquelle la phase de corrélation comporte la multiplication de chaque échantillon de rayonnement capté par l'un des signaux respectifs de modulation et l'intégration des multiples de signaux qui en résultent dans un cycle de modulation.

6. Méthode suivant l'une ou l'autre des revendications précédentes, selon laquelle la phase de capotage comporte le captage du rayonnement reflété par le substrat.

7. Appareil pour capter la présence d'encre sur un substrat, l'appareil comportant des moyens d'irradiation (1) pour irradier le substrat (2) avec un rayonnement situé à un minimum de deux longueurs d'onde, dont une des longueurs d'onde est sélectionnée pour correspondre à la longueur d'onde d'absorption ou de réflection de l'encre à capter; des moyens de modulation (5) pour moduler le rayonnement à chaque longueur d'onde de façon respective différente; des moyens capteurs de rayonnements (3) pour capter le rayonnement émis par le substrat; caractérisé en ce que l'appareil comporte en outre des moyens de corrélation (7,8) pour la corrélation d'échantillons de rayonnement capté à partir des moyens capteurs de rayonnement avec des signaux dont chacun est modulé par une des modulations respectives appliquée au rayonnement, pour générer des signaux de corrélation; et des moyens de surveillance (9) pour la surveillance des signaux de corrélation de façon à capter la présence de ladite encre.

8. Appareil selon la revendication 7, dont les moyens capteurs de rayonnement (3) comporte un capteur commun pour la réception du rayonnement à chacune des longueurs d'onde générée par les moyens d'irradiation (1).

9. Appareil selon la revendication 7 ou la revendication 8, dont les moyens de corrélation comportent une série de circuits multiplicateurs (7), un pour chaque longueur d'onde, chaque circuit multiplicateur recevant un échantillon du rayonnement capté par les moyens capteurs de rayonnement et un signal qui a été modulé de même façon que la longueur d'onde correspondant audit circuit multiplicateur; et des moyens intégrateurs (8) auxquels le signal de sortie du circuit multiplicateur est apporté, les moyens intégrateurs assurant l'intégration du signal d'arrivée sur un cycle de modulation.

10. Appareil selon l'une ou l'autre des revendication 7 à 9, dont les moyens modulateurs (5) provoquent la modulation de chaque longueur d'onde selon une séquence respective binaire pseudo-aléatoire.

11. Appareil selon l'une ou l'autre des revendication 7 à 10, dont les moyens modulateurs (5) provoquent la modulation du rayonnement à chaque longueur d'onde avec les versions respectives déphasées d'une séquence commune de modulation.

12. Appareil selon l'une ou l'autre des revendication 1 à 6, dont le substrat est un billet de banque.

Fig.1

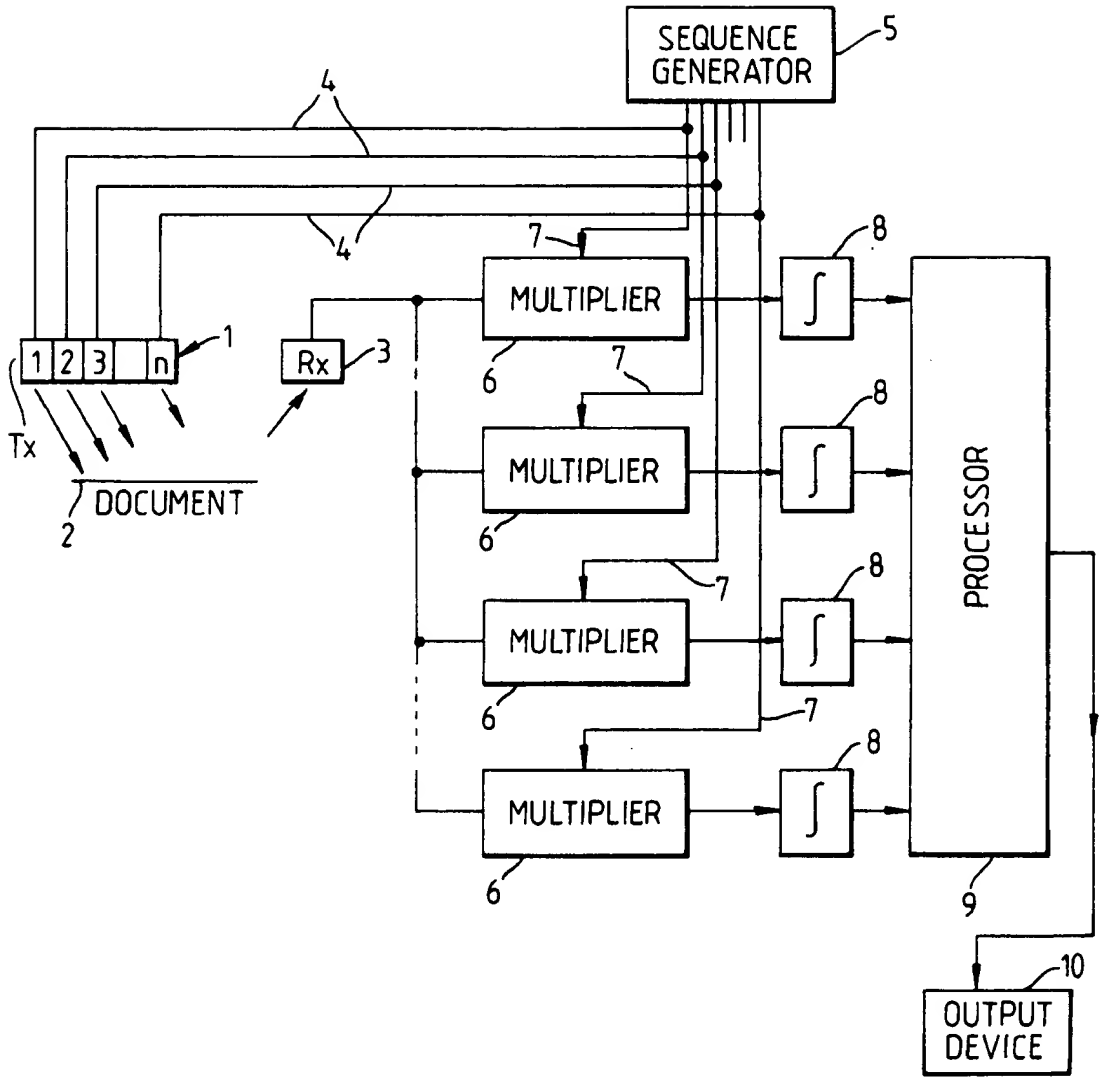
SEQUENCE GENERATOR
5
4
4
7
8
MULTIPLIER
6
7
8
MULTIPLIER
6
7
8
MULTIPLIER
6
7
8
MULTIPLIER
6
PROCESSOR
9
1
1 2 3 n
Rx
3
Tx
DOCUMENT
2
10
OUTPUT DEVICE

Fig.2A

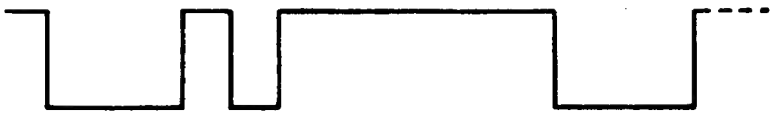

Fig.2B

Fig.2C

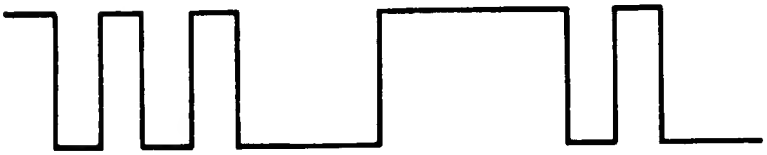

Fig.2D